(b) Because vessels in the Gulf of Mexico and the northwest Caribbean Sea for the days in question always showed winds inclined toward a single center.

(c) Because the barometers of these vessels and all those in the western part of Cuba during the 14th, 15th, and 16th; the direction and violence of the winds; the direction of the low clouds; everything pointed to the fact that the hurricane center that had passed a short distance to the west of Pinar del Rio had not traveled far, and never could it be admitted that it had disappeared.

(d) All the winds in the western part of Cuba, after the night of the 13th, correspond, according to known laws, to the lower part of a hurricane.

3. The path of a second hurricane south of Cuba, from the 14th to the 16th of October, is opposed to the observed facts.

4. The loop hypothesis has been accepted. The form and dimensions of the loop can not be determined exactly for lack of necessary observations; those known satisfy the path indicated.

The study made at the Central Office of the Weather Bureau by Mr. Wilfred P. Day confirms the presence of but one hurricane, which followed closely the track shown on figure 1.

It will be noted that in describing the loop the turning in all cases was counterclockwise. Whether this is invariable is not known.

These paths are presented as interesting and curious departures from normal cyclone tracks. The explanation is not obvious.

DISCUSSION.

By A. J. Henry.

The failure of cyclonic areas to move in the path predetermined for them by the forecaster, has wrecked many otherwise perfectly good forecasts. Naturally much attention has been devoted to the weather maps which provide good examples of failures to move in the ordinary path, and we are indebted to Supervising Forecaster Bowie for his note and illustrations of erratic paths in the cyclones which traverse the eastern United States.

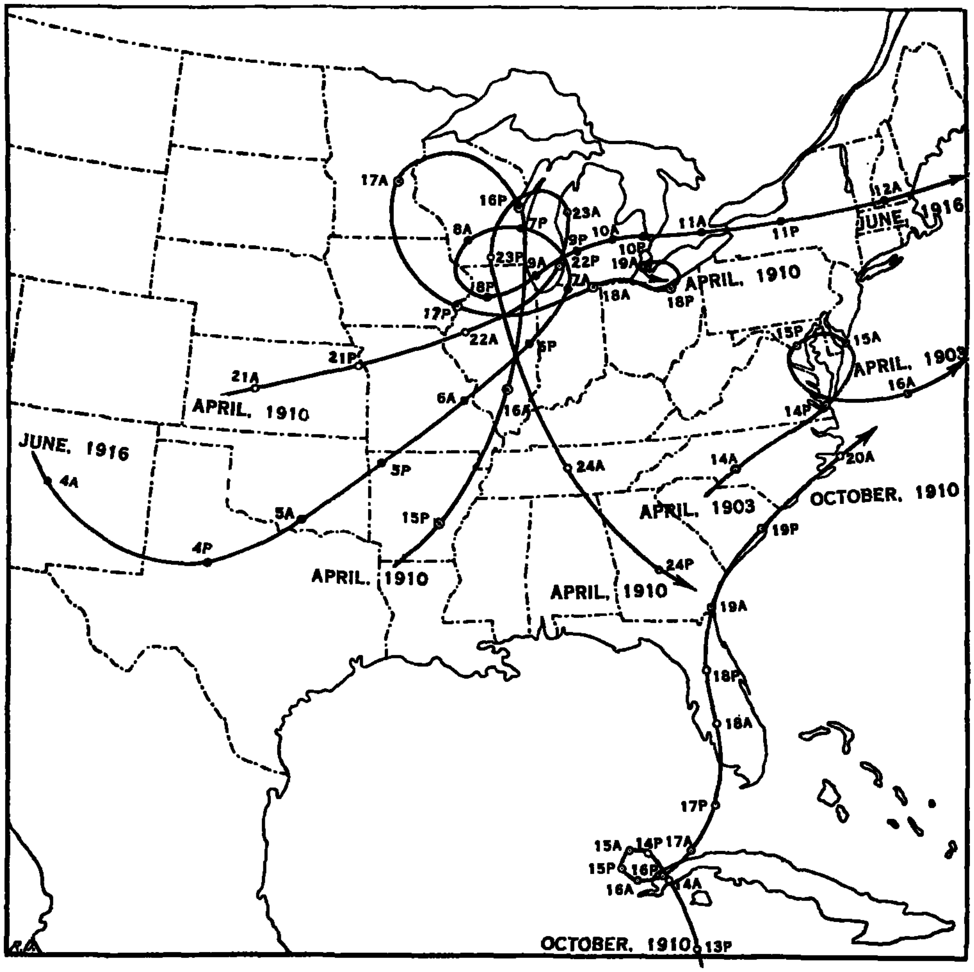

FIG. 1. Erratic cyclone paths.

We agree with his statement that the cause of the failure to move in the customary path is not obvious, nevertheless we can not but think that some discussion of the subject would be helpful. With the object of stimulating discussion the following considerations are offered:

A study of the pressure changes.—Copies of a number of the 12-hour pressure change charts of the forecast division have been made for the critical dates in most of the cyclonic paths presented in figure 1. Before entering upon a discussion of these charts it is necessary to describe in some detail the method of making them, and therefore the writer's apologies are offered for repeating what many readers may be familiar with.

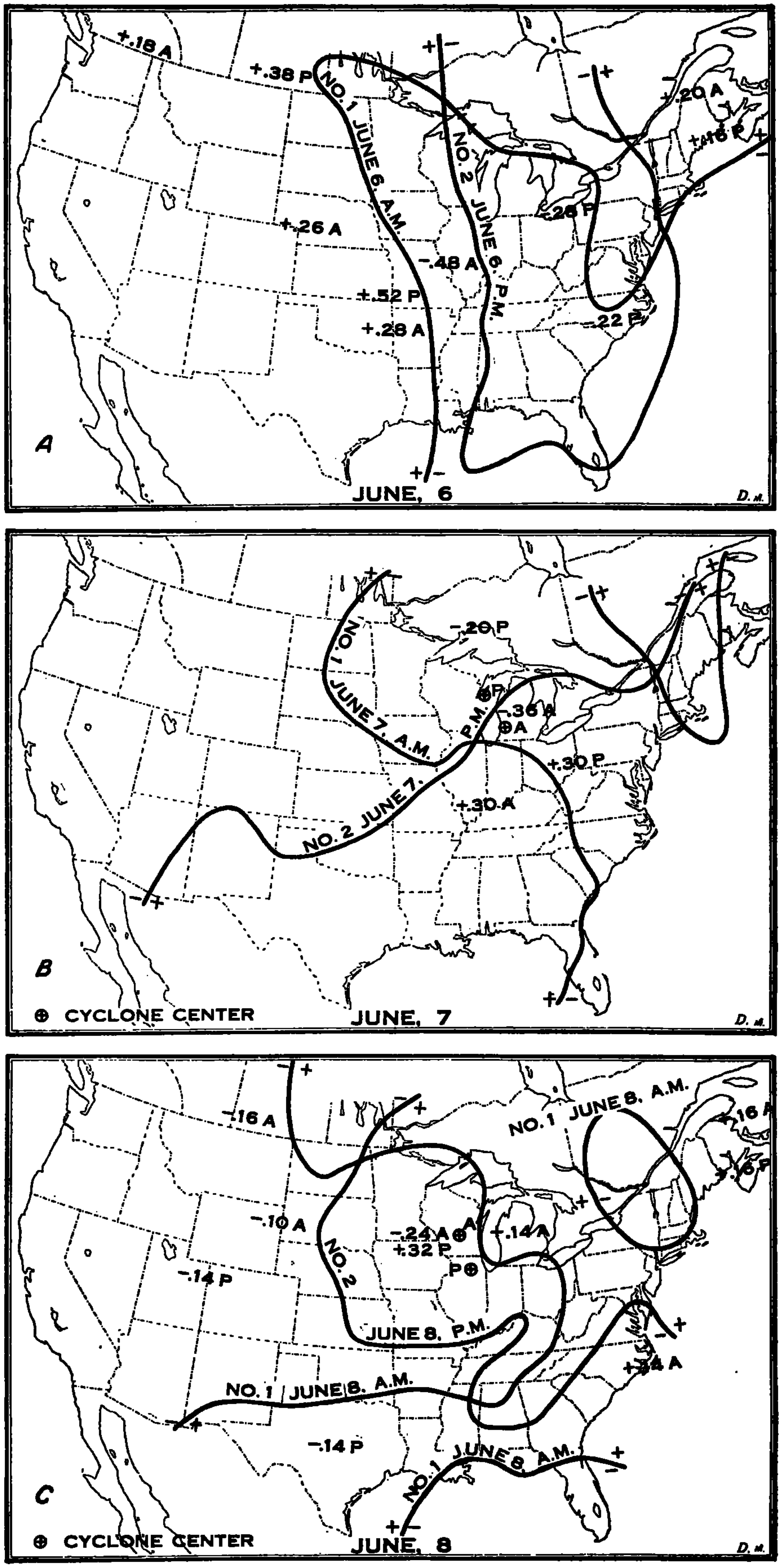

FIG. 2. Neutral lines of pressure change on dates of erratic cyclonic movement.

The pressure change charts prepared twice daily contain the following data: (1) The sea-level pressure at the station; (2) the departure of that pressure from the seasonal average; (3) the change in pressure since the preceding observation—the 12-hour change. After the data have been entered the charts are generalized by drawing, first, lines through the points where the 12-hour change is zero; these neutral or zero lines serve to divide the observational area into zones or regions of falling pressure and rising pressure, respectively. Ekholm has proposed the following names as descriptive of these regions: "Allobar," any area or pressure change, regardless of the sense of the change; "Anallobar," an area over which pressure has risen; "Katallobar," an area over which pressure has fallen.

After drawing the neutral lines it will be readily seen that these lines divide the observational area into systems of anallobaric and katallobaric lines. The next step is to draw these lines and give them their proper algebraic sign; the usual interval between these lines is a tenth of an inch of pressure change. Lines are drawn through points having pressure changes of equal magnitude, just as contour intervals are plotted on a topographic map with this difference—anallobaric lines are indicated by a plus sign and katallobaric by a minus sign. The completed map enables one to quickly visualize the changes in atmospheric pressure that have taken place in the last 12 hours, and since the process is a continuous one it is fair to assume that the change will continue in the same sense during the coming 36 hours or more.

In figure 2 are given the neutral lines only for the six 12-hour periods beginning June 6, 1916 (8 a. m., seventy-fifth meridian time); these six periods embrace the time during which the cyclone charted as beginning on June 4 of that year was deflected from its normal path in the vicinity of Lake Michigan. (See fig. 1.) In addition to the neutral lines, the greatest rise in the barometer in hundredths of an inch of mercury has been entered upon the charts in its appropriate geographical position; the greatest negative change has been treated in the same manner; and thus we are able to trace the progress along the earth's surface of the anallobars and the katallobars from day to day. The essential facts shown on Chart A of figure 2, for June 6 are: (1) In the morning the greatest pressure fall was 0.48 inch in the neighborhood of St. Louis, Mo., and it was concentrated in that region; 12 hours later the place of greatest surface fall in pressure was about 500 miles to the eastward; and now, instead of being concentrated in one spot, two separate areas of maximum fall appear, the first in the vicinity of Lake Erie, the second in northeastern North Carolina; the warping of the isobars over that region on the evening map of the 6th indicated that a secondary cyclonic circulation was developing to the southeast of the primary center. Pressure was rising both in the front and in the rear of the cyclone center, the greatest rise being immediately to the southwest; (2) the distance covered in the advance of the katallobar to the eastward during the daylight hours of the 6th was smaller than usual; note particularly that the neutral line at the p. m. observation had receded to the west of its position 12 hours earlier. This, I believe, was due to the rising pressure over the Canadian Maritime Provinces.

June 7, 1916 (8 a. m. and 8 p. m.).—Chart (B) of Figure 2: (1) Note especially the warping of the neutral line of the morning chart to the northeast over the upper Ohio valley and to the westward across Iowa and that the fall in pressure at the surface has apparently moved north-northwest across Lake Superior, its movement in that direction being facilitated by rising pressure directly to the south; (2) pressure is rising over New England, though to a less degree than on the previous day.

June 8, 1916 (8 a. m. and 8 p. m.).—Chart (C) of Figure 2 is on first sight the most complicated of the series. The sharp bends in the neutral lines suggest a local surface effect at places which has not been eliminated. In studying this chart it is important to compare neutral line No. 2 of the immediately preceding chart with neutral line No. 1 of Chart (C). Thus it will be seen that the katallobar whose longer axis has been in a north-south direction is now in a nearly east-west direction and that there is a great bending to the eastward of neutral line No. 1 in the morning and a retrograde movement in the evening or No. 2 line. This retrograde movement seems to have been due to a sharp recovery in pressure in the vicinity of the cyclone center at 8 a. m. of the 8th of July. Note also that pressure continues to rise over the Canadian Maritime Provinces. The sea-level pressure at Father Point—mouth of the St. Lawrence River—rose from 29.96 at 6 a. m. July 6 to 30.40 inches at 8 a. m. of the 9th, thus indicating the movement of an anticyclone across the normal path of the cyclone of July 7, which was then centered over Lake Michigan, and this movement may have been the direct cause of the failure of the cyclone to immediately follow the normal path. The conditions from the 9th to the 10th, when, as may be seen from Figure 1, the cyclone again took up a normal course of progression, may be summarized as follows: An anticyclone, as just stated, was centered at Father Point, Quebec, on the morning of the 9th. At the evening observation of that date the center had apparently moved to the southeast as far as Sydney, Cape Breton Island, where the pressure was 30.48 inches. The anticyclone remained in this location until the morning of the 12th; at that time pressure began to fall, thus permitting the approach of the cyclone which we have been considering. The latter, it may be remarked, had in the meantime lost most, if not all, of the characteristics of a cyclone, and soon thereafter disappeared because of rising pressure in its center.

The path of the cyclone of April 15–18, 1910, has been examined in like manner. In this case pressure rose at Father Point, Quebec, from 29.84 inches on the morning of the 15th to 30.38 inches by the morning of the 17th. The retrograde movement of this storm began during the afternoon of the 16th, when pressure over the mouth of the St. Lawrence was 30.32 inches and rising. The pressure distribution along the track of the cyclone of April 21–24, 1910, differs in some details from that of the two storms above considered, but it is similar in that pressure over the Canadian Maritime Provinces was rising at the time the cyclone began its abnormal path. The large sweep of the latter from its position near Madison, Wis., on the evening of the 23d to Nashville, Tenn., is an illustration of cases, not infrequent, when the apparent movement may not be real. Pressure rose sharply in the center of the cyclone in the 12 hours 8 p. m., 23d, to 8 a. m., 24th; at the same time a katallobar moved from Oklahoma to Nashville, Tenn., by the 8 a. m. observation of the 24th; these two events—rising pressure in the cyclone center and falling pressure to the southeast—conspired to give the lowest pressure at Nashville, although pressure was still lower to the east, as in North Carolina. As between the two propositions, first, that the cyclonic system of winds and pressure was transferred bodily from Madison to Nashville, or second, that the original cyclone was destroyed by rising pressure—filled up, as it were—and that a secondary cyclone formed to the southeast, the formation of which was facilitated by the arrival of a katallobar from the west, I would say that the second appears to be the most probable, but, however that may be, the fact remains that the northeastward progress of the cyclone was interrupted on the 23d, probably by the filling up of the cyclone *in situ* and the development of anticyclonic conditions—rising pressure over the Canadian Maritime Provinces. The cyclone of April 14–16, 1903, only remains to be examined. In this case the cyclone advanced to southern New Jersey by the morning of the 15th; it then made a loop to the west, continuing its turning motion counterclockwise and passing over the Virginia capes to sea on the early morning of the 16th. The pressure at Sydney, Cape Breton Island, directly in its normal path, rose from 29.78 inches on the morning of the 13th to 30.20 inches on the morning of the 15th at the time the abnormal course of the cyclone began.

I am unable to offer any suggestion as to the cause of the loop in the tropical storm of October, 1910, although logically its progressive movement should be subject to the same disturbing influences as are operative in the case of extratropical cyclones.

REMARKS UPON THE INTERPRETATION OF ALLOBARIC CHARTS.

The series of allobaric charts of the Weather Bureau now extends upward of 40 years and a considerable number of forecasters have had greater or less experience in the application of the information conveyed by these charts to the practical problem of weather forecasting from synoptic charts.

At least 95 per cent of this experience is lost to future workers because of the failure on the part of those possessed of the experience to commit it to writing.

The natural disinclination to reduce their precepts to writing may be explained on the assumption that there was and is a lack of any clear understanding of the physical phenomena which form the foundation of these charts.

Everyone who has given attention to the subject knows that falling pressure is an almost invariable accompaniment of cyclones and that, conversely, rising pressure, in a somewhat less degree, is an accompaniment of anticyclonic winds and pressure distribution. Rising pressure is sometimes, as it seems, merely the local reaction toward higher pressure, in which case it probably does not extend upward to any considerable altitude and does not signify the oncoming of anticyclonic conditions.

It is also a commonplace in the experience of forecasters that the intensity of development of strong cyclonic and anticyclonic conditions is measured by the rapidity with which the changes in surface pressure take place and also in a lesser degree to the geographic extent covered by them.

These two general conclusions may be regarded as fully established on the ground of human experience; when, however, we attempt to penetrate beyond their immediate range the limit of our knowledge is remarkably small. The literature of the subject is not large; that available to readers of this REVIEW is summarized by Dr. Hanzlik.[1]

It is to Ekholm, however, that we are indebted for much of the literature on the subject, especially as it applies to European cyclones. In a recent communication to the Weather Bureau Ekholm points out that the summary of Sresnewsky's work as quoted by Hanzlik is best expressed as follows when translated into English:

> From 23 instances he finds that the strongest fall of the barometer is going on, not in the path of the cyclone, but to the right of it, and that the future course of the center of the cyclone is directed not toward the place where the barometer is falling most strongly, but to the left of it. According to Sresnewsky this is explained by the great eccentricity of the outer isobars of the cyclone, the isobars on the right side of the cyclone being much nearer to each other than on the left side. There are, however, many exceptions to the rule. On this point Sresnewsky remarks: Relatively frequently it occurs that the minimum (cyclone) moves directly to the point where the barometer fell most strongly at the preceding term; sometimes, however, the distance between the center of the minimum and the point [place] of the greatest fall of the barometer becomes extraordinarily large. Thereby it happens that the connection between the minimum and the falling of the barometer becomes totally disturbed; the minimum remaining immobile at a point; the rarefaction of the air propogates itself in the form of a wave in any direction, going away more and more from the minimum.

The experiences of forecasters in the United States, are, I think, in general accord with the foregoing, except the last sentence, and in regard to that it is not clear what is meant by "the rarefaction of the air propagates itself in in the form of a wave in any direction, going more and more from the minimum."

The following suggestion by Hanzlik[2] commends itself to the writer:

> I am inclined to believe that in the areas of fall and rise we have found something independent of the LOW, something primary, and that the LOW, by its distance from them, regulates its own velocity. * * * I would bring these moving areas of falling and rising pressure in close connection with both the currents producing the LOWS, namely, the cold northerly winds with the areas of rise, and the warm southerly winds with the areas of fall, because, first, the extreme temperature changes lie within the areas of rise and fall, and second, these two currents are the primary cause of the LOW.

When it is considered that the axis of the LOW is inclined backward, at a considerable angle, we may well inquire is the fall in pressure which is portrayed on allobaric charts to be referred to the very lowest levels in the superincumbent air or perhaps to the 4, 5, or 6 kilometer level? In other words, at what level in the free air is the action going on that results in a fall in surface pressure and also, in a manner not clearly understood, forms the guiding force in the progressive motion of the cyclone? Another problem which forces itself upon the forecaster is how shall he explain the fact that areas of falling pressure are not coextensive, on the surface at least, with the cyclones to which they belong? The north-south extension of areas of falling pressure is many times greater than its east-west extension, and somewhere at the intersection of the two axes the fall or rise in pressure, as the case may be, is at a maximum, diminishing thence in all directions.

As Hanzlik has already pointed out, there is an almost unworked field of study in a correlation of the movement of cyclones and anticyclones and the areas of falling and rising pressure that accompany them.

In conclusion, three points in connection with the abnormal paths in Figure 1 stand out prominently: First, that the temporary blocking in the path of the cyclone in every case takes place in the neighborhood of a water surface; second, that the turning in the path of the cyclone is in a counter-clockwise direction, and third, that in each case of temporary blocking, excepting only the tropical storm of October, 1910, pressure rose over the Canadian Maritime Provinces. In my opinion the last named is the most probable cause of the erratic movement as described and illustrated.

[1] Hanzlik, S., Relations between velocities of progression of lows and the areas of rising and falling pressure that accompany them. MO. WEATHER REV. 34: 205.

[2] *Loc. cit.*, p. 208.